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Abstract

EXPERIENCE WITH THE CHEMISTRY OF WATER IN MODERATOR AND COOLANT SYSTEMS

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1. This paper summarizes information from the NRX, NRU and NPD reactors and from experiments in in-reactor loops cooled by pressurized water, boiling water or steam-water mixtures (fog).

RADIOLYTIC REACTIONS IN MODERATORS

2. The steady-state concentrations of dissolved deuterium formed by radiolytic decomposition vary from 1 to 5 cm^3 (STP)/kg D_2O. Temperature, pD and other undefined factors affect the radiolytic equilibria. The net rates of decomposition vary from ~0.4 to 30 liters (STP)D_2 per MWh of total reactor output and depend on the rate at which dissolved gas is transferred to the helium atmosphere over the moderator.

3. With an air-to-helium ratio of 1:1 in the atmosphere at the top of the NPD reactor vessel, about 1 g mole of nitric acid is produced per day. This rate depends linearly on the total volume of nitrogen gas present.

RADIOLYTIC REACTIONS IN COOLANTS

4. In pressurized-water systems a hydrogen or deuterium concentration of 5 cm^3/(kg water) is adequate to maintain oxygen below 0.01 cm^3/kg and to suppress oxidation of magnetite.

5. In boiling water and fog the addition of ammonia suppresses oxygen production without the formation of worrisome amounts of nitrate. At 5×10^{-4} M ammonia less than 0.01 cm^3 of oxygen and less than 0.01 mg

of nitrate are formed per kilogram of steam produced. When gases are continually stripped from the system, some ammonia decomposition occurs. When gases are not removed, equilibrium conditions are reached at moderate gas concentrations and net decomposition approaches zero.

CORROSION-PRODUCT TRANSPORT AND DEPOSITION

6. In systems made of carbon steel or stainless steel and cooled by pressurized water, boiling water or fog, the water contains filterable corrosion products at a concentration between 0.001 and 0.01 mg/kg. The amounts of colloidal and soluble corrosion products are generally in the same range. After several months in these systems Zircaloy fuel sheaths show deposits of corrosion products in the range from 10 to 200 $\mu g/cm^2$, all less than 1 μm in thickness.

RELEASE FROM DEFECTED UO_2 FUEL ELEMENTS

7. Irradiation of defected UO_2 fuel elements of different lengths operating at high power ratings has shown that gaseous and volatile fission products with half-lives less than a few hours are released to the coolant only from a small volume of fuel near the defect. Thus, release is controlled both by diffusion out of the UO_2 matrix and by slow movement along the fuel element to the defect.

8. Uranium released to the coolant deposits on system surfaces. Typical values on Zircaloy are 0.01 to 5 $\mu g\ U/cm^2$ depending on the size of defect and the time of exposure. The deposition is reversible and is related to the concentration of dissolved uranium in the coolant; however, rates of desorption are very low.

9. Power cycles cause the transient release of large amounts of fission-product activity. The resultant responses of delayed-neutron and gamma monitors are dependent on the rate and amount of the power increase, and can be used for locating defected fuel in a large reactor.